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Independent Evaluations of the LTSY Model's Accuracy

The Pacific Lumber Company
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A review of the methods used in forest projection for Pacific Lumber

by

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In this report I review the procedures used by the Pacific Lumber Company and its consultants (VESTRA resources) to project forest resources over time. I have reviewed the materials made available to me which include: {Draft Report: Calibration of Freights Models 6/20/96 and The Document Procedures and Assumptions (for producing the timber volume estimates) **by** Hammon, Jensen, Wallen and Associates}. My review comments are based on these materials, and additional conversations with Mr. Henry Alden on these procedures. I have not reviewed the computer code and datasets used to make these projections.

Summary
Overall I find that the procedures chosen by the Pacific Lumber Company and its consultants were reasonably selected. The biggest problem which exists is lack of sufficient data for which to make yield projections. It is impossible to know if these choices provide accurate yield estimates without adequate data to judge the growth of particularly the intensively managed stands. Nonetheless the projections appear to be conservative and hence true yields are expected to surpass those projected. In the future additional inventory plots are needed to provide accurate growth information in both extensively managed and intensively managed stands. More precise tracking of harvest dates and improved estimates of site index for the land holding will also help to improve the overall accuracy of the yield estimates.

Review of forest growth procedures:
Historically. most of the Pacific Lumber Company's lands were harvested in the late 1800's to early 1900's. Most of the redwood and Douglas-fir of significant size (> 36" DBH) was removed in these harvests. These residual stands been left to grow and have not received intensive management inputs such as thinning, fertilization or control of competing vegetation. Pacific Lumber refers **to** these as **extensively managed stands.**

In contrast, a smaller portion of the land base which has been clearcut has received some **of** the intensive management inputs listed above. These are referred to as intensively **managed stands.** However, with minor exception. these stands are younger than 10 years in age

Extensively managed stands

The two major systems for projecting forest growth include using traditional yield tables which project whole stands. and individual tree growth models which project how individual trees will grow. Yield tables need age and site index in order to predict how stands grow.

Age

Precise ages of the extensively managed stands was not known. However, the cutting history indicated the decade in which the original harvesting occurred. Using the center of the decade of harvest as a proxy for age means that the true age is within ± 4.5 years. This level of error should not appreciably affect the yield projections.

Site index

Site index is one of the most important variables in determining yield. Although there has been some work in the Pacific Northwest correlating site index to soil properties, in general this technique has not achieved the level of accuracy desired. To use this procedure first soil types are correlated to site index. Then in other areas the soil type is used to estimate the site index, or quality. For Pacific Lumber lands most soil types were predicted (classed) to be site II using this method. This shows that difficulty in predicting site quality solely as a function as soil type. Selecting Krumland and Wensel site curves is appropriate because they are widely accepted and used in the redwood - Douglas-fir forest type and are regarded as accurately portraying the height growth development of dominant second-growth trees. Alternatively the Lindquist and Palley curves could be used because they are quite similar to those of Krumland and Wensel.

The vast majority of the extensively managed stands are site II. According to Henry Alden, there are very few site I, III and IV areas, with most of the property being Site II. The average site index (Krumland and Wensel base age 50) for Site II was 100 for redwood and 125 for Douglas-fir.

Watson, Krumland and Wensel (1979) give conversions between site classes from different systems. For redwood they have the following conversions:

Site Class	Krumland & Wensel 50 year base	Lindquist and Palley 100 year base
I		
II	102-l 114-123 14	155-170
III	91-102	140-155
IV	81-91	125-140

Each drop in Site Class, say from I to II, causes about a 10 foot decrease in the site index of Krumland and Wensel which corresponds to about a 10% decrease in volume production for each drop in Site Class. Because of this an acre of Site Class I yields approximately the same volume as 1.10 acres of Site II.

Yield table projections

One possibility for projecting redwood growth is to use Lindquist and Palley's 1963 yield tables for predicting stand growth. The stands that were sampled for this table were even aged unmanaged relatively pure stands of redwood. The average initial basal area of the sampled stands was 305 ft^2 with a standard deviation of 190 ft2. With this much variation in initial stocking conditions the Lindquist and Palley stands can not be considered to be "normally" stocked. Lindquist and Palley state "Sampling carried out for compilation of the present tables sought stands that were typical of better stocked conditions occurring within this type”. Thus. these are empirical yield tables representing growth of better stocked stands. It is widely recognized that normally stocked stand conditions rarely exist and generally overestimate yields. The empirical yield tables of Lindquist and Palley may still overestimate yields particularly if the current stocking levels are significantly different from those used to create the table.

For Douglas-fir, Schumacher’s normal yield tables could be used for projection. These tables, however, are clearly from normally stocked stands and will overestimate the yield of non-normal stands. None of the commercial stands in existence today can be considered to be normal stands.

CRYPTOS and FREIGTHS

CRYPTOS is an individual tree simulation model developed at the University of California (Krumland and Wensel, 1982). It has been widely used and is generally viewed as providing fairly accurate short-term projections. Datasets to perform long-term validations are extremely rare or non-existent.

FREIGHTS (Forest Resource Inventory, Growth, and Harvest Tracking System) is a new forest simulation system that can be used for coastal redwood and Douglas-fir. Its major design advantage is that is allows for more sophisticated harvesting and silvicultural manipulation than CACTOS or CRYPTOS allows. In addition FREIGHTS was designed to operate on a entire land holding’s data, not a small set of plots for which CACTOS and CRYPTOS operate best

Louisiana-Pacific Corporation recently contracted with the University of California to undertake an independent validation of FREIGHTS. In the report to Louisiana-Pacific Biging, Gill and Barrett compared the projections from CRYPTOS to those of FREIGHTS over a variety of stand conditions and concluded that FREIGTHS and CRYPTOS produces very similar projections. Unfortunately, they were not able to validate either of these coastal models because of the paucity of long-term validation data on which to make the comparisons.

Calibration of redwood growth with FREIGHTS

The primary ways in which FREIGHTS can be calibrated **is** through adjustments to the height and diameter growth equations. To do this, however, a sufficient amount of growth data needs to be available to adjust the model to match observed growth. In the absence of this type of calibration data. FREIGHTS can be calibrated with other ad hoc methods so that the volume estimates it makes matches the volumes observed on the extensive management land holdings. This can be done by in essence making a yield table. The yield over time (decade) can be plotted and FREIGHTS can be adjusted (in number of trees per acre by species, DBH and height) until the predictions match the actual yields. Even though this procedure is ad hoc, it is actually superior to the situation where we have good calibration data, but of a limited time period. In this latter case the odds are much higher for making long-term projection errors with the model.

In Draft Report on the calibration of the FREIGHTS model (hereafter simply referred to as the Draft Report) it is reported that the FREIGHTS growth estimates match a CRYPTOS simulation which used Barrett model output followmg clearcutting (Barrett, 1988). It is also reported that the FREIGHTS calibrated yield predictions agree well with a localized yield table that Louisiana-Pacific at Crannell developed. I have not reviewed these two studies to check for the accuracy of these statements. Assuming they are correct they lend collaborating evidence for using the ad hoc calibrated FREIGHTS model for projecting the extensively managed stands. Clearly, however. in the long run datasets need to **be** developed that will provide a sufficient test to judge the accuracy of the projections to the true growth and yield on the intensively managed **stands.**

Douglas-fir yield using normal yield tables

The procedure used was to utilize Schumacher's normal yield tables, for site 120. and reduce them by 25 percent. Schumacher's original data for these tables came mostly from the coastal range of California. Over 25 percent of the plots occurred on Pacific Lumber's land holdings. Thus, the yield tables are particularly appropriate for predicting the maximum yields of this species. The average site index for Site II Douglas-fir on the property is 125. Choosing a 25 percent reduction from the normal yield tables appears to be a reasonable selection. Of course, in the long run. sufficient **data** needs to be collected so that a individual tree growth model like FREIGTHS can be directly calibrated.

Intensive Management

The intensively managed stands are capable of producing volumes considerably greater than their extensively managed counterpart. The Scotia Tree Farm offers some insight into the possible yield improvements from control of competing vegetation and plantation spacing. It currently has the following averages (8.6 in. DBH, 34 ft. average height, 550 TPA, 238 ft^2 BA, 6 MBF/ac). If the plantations keep growing at the current observed growth rates in five years they will reach an average yield of 16.5 MBF/ac.

How does the yield of these plantations compare to the yield predicted **with** yield tables? Assuming 2 years to reach breast height, the 12-15 year old plantations **have** a breast height age of 10-13 years. The average height is 34 feet. This corresponds to a approximately a redwood site index of 120 (Krumland and Wensel, 1977) or approximately 180 using the 100 year base-age site curves of Lindquist and Palley. The empirical yield tables project a board foot (International l/4 inch rule) volume per acre of 14,500 at age 20 for site 180.

Scribner volumes for 16 foot logs can be approximated by: v = $0.79D^2 - 2D$ -4. The equation for International 1/4 inch volumes for 16 foot logs is: v = $0.88D^2 -$ 1,520 – 1.36. The ratio of Scribner to International volumes is given in the table below for selected log diameters (D). I chose a conversion of 0.80 to represent the conversion for the mix of logs contained in a stand of average diameter projected to be 13 inches. After applying this factor it yields an estimate of 11.6 MBF Scribner. This is approximately a 25% increase over the estimate of yield from Lindquist and Palley's tables. This value is less than that estimated in the Draft Report. The discrepancy in these two values is likely due to the factor chosen to convert International l/4 inch volumes to Scribner volumes. Nonetheless. both figures point to substantial increases in volume production for the intensively managed stands relative to the yield table projections.

Scribner **and International 1/4 inch board foot volumes by log diameter**

log diameter	Int. 1/4 inch	Scribner	Scribner/Int.
10	71.4	55.0	0.77
12	107.1	85.8	0.80
14	149.8	122.8	0.82
16	199.6	166.2	0.83
18	256.4	216.0	0.84

It is fairly well established that intensive management of forest stands can result in substantial gains over that indicated in yield tables. The types of activities which may be undertaken include control of competing vegetation, fertilization, use of improved genetic stock. thinning, and pest control. For example. Hopmans and Chappell (1994) report that for young Douglas-fir stands in the Pacific northwest there was a growth response over 8 years in basal area of approximately 24% and 18% in volume following fertilization with nitrogen at 224 kg/ha. However, in some locations the volume response was 60-120%, but in others it was less than 10% due to differences in concentration of nitrogen in the foliage of trees at the various sites.

Herbaceous vegetation control has been shown to consistently increase height and diameter growth of conifer species such as loblolly pine and Douglas-fir (Harrington and others. 1991). Knowe (1994) found that total vegetation control significantly increased the rate of height growth of young Douglas-fir trees in plantations because it reduced moisture stress and increased foliage biomass. This form of treatment can increase dominant height by 2m by age 15. Powers and others (1992) found that herbicide treatment was the most important factor for increasing growth of Ponderosa pine in California in the first four years after planting. The average increase in volume on the herbicide treated plots was 176%. but ranged from 6 - 755%.

As pointed out in the Draft Report little or no literature exists on the long term effects of intensive management Thus while many studies clearly show substantive short-term gains due to intensive management, it is prudent to conservatively estimate the long-term gains. It is rational to believe that the long-term productivity gains will be less than the short-term gains. Vegetation control is a case in point For this management treatment the gains in productivity is expected to level off as stands achieve crown closure (Powers and others, 1992).

The Draft Report assumed that the intensive management of 60 year old redwood would be limited to a 15% gain in volume yield over that given in the yield tables for Site II Douglas-fir (Lindquist and Palley site 160 at base age 100). A fifteen percent gain in volume yield for this species is likely conservative. It can be expected that productivity gains beyond 15% in volume are feasible with combinations of genetic improvement, control of competing vegetation, and pest control. Obviously assuming that Douglas-fir under intensive management could reach the volume indicated in Schumacher's normal yield tables is also a conservative estimate.

As better data become available adjustments to yield projections can be made reflecting the experimental differences between even and uneven-aged management regimes.

Conclusions

Overall I find that the procedures chosen by the Pacific Lumber Company and its consultants were reasonably selected. The biggest problem which exists is lack of sufficient data for which to make yield projections. It is impossible to know if these choices provide accurate yield estimates without adequate data to judge the growth of particularly the intensively managed stands. Nonetheless the projections appear to be conservative and hence true yields are expected to surpass those projected. In the future additional inventory plots are needed to provide accurate growth information in both extensively managed and intensively managed stands. More precise tracking of harvest dates and improved estimates of site index for the land holding will also help to improve the overall accuracy of the yield estimates.

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Mr. Henry Alden, **Forest** Manager
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Scotia CA.

Dear Henry,

I appreciate the opportunity to make a general comment on the accuracy and credibility of the analytical model used by PALCO. My remarks are restricted to the modeling of how forest stands on the PL **forest will change, develop, and provide harvest if managed with different silvicultural prescriptions and policies I do not address the** merits of any particular policy.

As you know I helped to design and develop the strategic forest planning system called EP(x), with the staff of VESTRA Resources. This system is being used by Louisiana Pacific Co. and Jackson State **Forest** as well as yourself to develop Sustained Yield Plans in California. The purpose of the system is answering the "what if' question; "if a given **mix of prescriptions is implemented on the lands of the forest, how will the vegetation strueture of the forest change and develop over time in terms of size, species, density and canopy structure?" If the** answer is based on ample and high quality on-the-ground inventory plots. an accurate current vegetation map and uses tested and validated growth simulation models, then the **answer** will be technically credible, **A** robust strategic planning model will enable landowners to consider many **such what if questions for many prescriptions and land types, thereby allowing many different policies for forest use to be considered and evaluated.**

The EP(x) system, as applied to PALCO's 200,000 acre forest, was based on over 5000 full tree **list inventory plots and a high resolution ground-checked current vegetation map to a minimum stand or parcel Size of 10 acres. This amounts to a plot for every 40 acres and provides a statistically reliable sample to** represent **each of** the important size and density classes by **watershed. By contrast, a typical National Fore** plan will be based on a plot for every 1000 to 2000 **acres and less reliable vegetation maps The 190** different prescription types and timing choices in PALCO's model allowed hundreds of thousands **of the "what-if" questions** to be **credibly answered. The Freights simulation model that generated the "what-if"** answers is based on the extensively used CACTOS redwood growth simulator and has been checked against published yield tables, inventory data and actual growth measurements on the forest, and was four adequate by an independent validation study.

In my opinion, the PALCO application of EP(x) is about the most accurate and spatially well detailed forest strategic planning models yet developed for any large landscape ownership in the United States This is especially true with regard to their projections **of vegetation structure and wildlife habitat for a width** range **of** policy end silvicultural options. I base this opinion on over 35 years of academic **and** professional **experience in working with, writing about, ad building models for strategic forest planning.**

Sincerely yours.

Lawrence S. Davis